

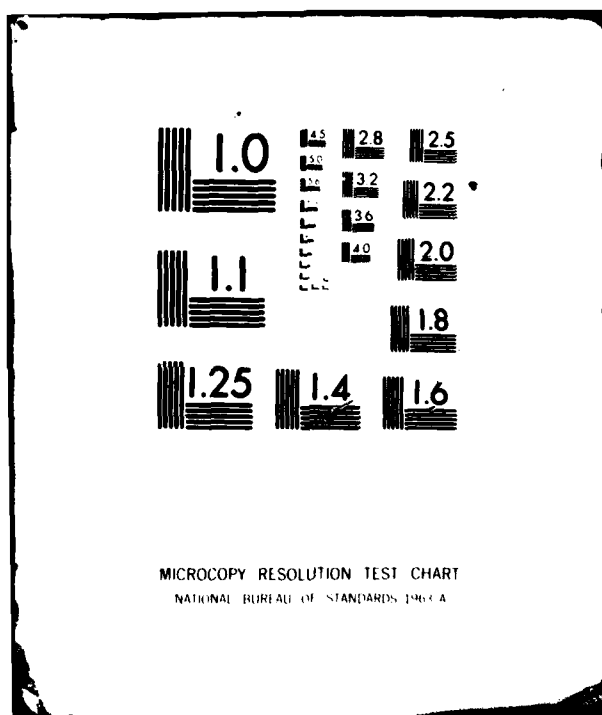
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Progress Report PR-79-23

LEVEL III

PHYSIOLOGICAL INFLUENCES UPON THE  
WORK PERFORMANCE OF MEN AND WOMEN

By

Raymond H. Kirby

Nancy K. Eberhardt

and

Glynn D. Coates

Final Progress Report  
For the period November, 1, 1977 - October 31, 1979

Prepared for the  
United States Air Force  
Air Force Office of Scientific Research  
Bolling Air Force Base  
Washington, D. C. 20332

Under  
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hours. In addition, the research plan provided comparisons of data obtained on female subjects to data of other studies using male subjects employed in the same work situation.

Central to the conduct of the research project was the use of the synthetic-work methodology that has been successfully employed in similar investigations using subjects from the male population. A brief summary of the philosophy and history of the synthetic-work methodology and a more detailed elaboration of multiple-task performance battery are presented.

The research project called for a total of seven studies completed during a two-year period with each of the studies conducted in three phases. In each of the studies, the first phase (Training phase) required the subjects to perform the tasks of a multiple-task performance battery for a total of 48 hours, performed in 4-hour blocks distributed over two to four weeks. This phase was required to insure that the subjects were operating at asymptotic levels of performance. The second phase of each study (Sleep-Loss and Continuous-Work phase) was devoted to the investigation of the combined effects of phase of the menstrual cycle (i.e., menstruation or midcycle), type of cycle (i.e., normally cycling or contraceptive pill), and 48 hours of sleep loss and continuous work performance. The final phase of each study (Cycling phase) required the subjects to perform the tasks of the multiple-task performance battery for an additional five weeks of 12 hours per week and provided an assessment of the effects of ovarian cycling on asymptotic performance.

In addition, seven supporting laboratory projects were conducted during the reporting period. Two annotated bibliographies were compiled on (a) the physiological changes associated with the menstrual cycle and their effects on behavior, and (b) the psychological or subjective effects of the menstrual cycle. Interim technical reports have been completed that report the details and results of the primary project, the supporting laboratory studies, and one of the annotated bibliographies.

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PHYSIOLOGICAL INFLUENCES UPON THE WORK PERFORMANCE  
OF MEN AND WOMEN

By

Raymond H. Kirby, Nancy K. Eberhardt and Glynn D. Coates

INTRODUCTION

This is the final progress report of work completed under U.S. Air Force Office of Scientific Research Grant No. AFOSR-78-3512. This project on "Physiological Influences upon the Work Performance of Men and Women" has been conducted under the direction of Drs. Glynn D. Coates (Professor of Psychology) and Raymond H. Kirby (Professor of Psychology), co-principal investigators, of Old Dominion University, Norfolk, Virginia.

This report covers work completed during the grant period of 1 November 1977 through 31 October 1979. Work during this period has been concentrated in the following areas:

- a) Final design of studies on the effects of 48 hours of sleep loss and continuous work on Multiple-Task Performance Battery (MTPB) performance.
- b) Preparation of MTPB equipment, work schedules, and data sheets for long-term studies.
- c) Data collection of background data on basal body temperature and predictability of onset of menstruation.
- d) Selection of subjects for seven long-term studies (BRASP-1 thru BRASP-7).
- e) Data collection, summary, computer analysis and preparation of the PAL Interim Technical Report (ITR) for the BRASP studies.
- f) Design, data collection, data analysis and preparation of the ITR for supporting laboratory study on the effects of the menstrual cycle on the capacity for physical work in women.

- g) Design, data collection, data analysis and preparation of the ITR for supporting laboratory study on the effects of sleep loss, sex, and S-R compatibility on information processing.
- h) Design, data collection and data analysis for two supporting laboratory studies on the effects of sleep loss and sex on critical flicker frequency.
- i) Design, data collection and data analysis for supporting laboratory study on the effects of sleep loss and sex on psychomotor performance.
- j) Design, data collection and data analysis for supporting laboratory study on the effects of sleep loss and sex on memory.
- k) Compilation of an annotated bibliography of the physiological changes associated with the menstrual cycle and their effects on behavior and preparation of ITR.
- l) Compilation of an annotated bibliography and the psychological (subjective) effects of the menstrual cycle.
- m) Design, data collection and data analysis for supporting laboratory study on the effects of 48 hours of sleep loss on field dependency.

#### WORK SUMMARY

##### 1. Design of MTPB Studies

Background--The primary objectives of this research project, as stated in the proposal, are as follows:

To conduct a study in which six crews of five women each are (a) trained to a level of asymptotic performance on the MTPB, (b) assessed for their performance on the MTPB for a period of four weeks in which a total of 48 hours of work behavior will be performed, (c) assessed for the effects of 48 hours of continuous work and sleep loss preceded by 16 hours of baseline performance measurements, and (d) assessed for recovery from the effects of the continuous work through an additional 16 hours of performance measurements. The crews will represent different conditions of ovarian and diurnal cycling.

Central to the research project are the tasks and concept of the multiple-task performance battery (MTPB) which has been successfully employed in the assessment of the effects of continuous work and sleep loss in males (cf. Alluisi, Chiles, & Hall, 1964; Alluisi & Chiles, 1967; Morgan, Brown, & Alluisi, 1974; Morgan, Brown, Coates, & Alluisi, 1974; Alluisi, Coates, & Morgan, 1977). Typi-



cally, the tasks of the MTPB are employed to create within the laboratory a synthetic-work situation in which systematic assessments of work behavior can be made.

In the synthetic-work usage of the MTPB, the tasks are displayed on identical operator panels located at each of the five semi-isolated work stations--one for each member of a 5-person crew. Subjects are usually run in groups of five, and the various tasks are presented concurrently to all crew members. Three watchkeeping tasks are used in the MTPB to measure the performance of watchkeeping, vigilance, and attentive functions (warning-lights, blinking-lights, and probability monitoring). Three active tasks (arithmetic computations, target identification, and code-lock solving) are used to measure the performances of memory functions, sensory-perceptual functions, and procedural functions, respectively. Detailed descriptions of these tasks may be found elsewhere (Morgan & Alluisi, 1972).

The six tasks of the MTPB are synthesized with the panel and a recurring 2-hour work schedule into a reasonably realistic work-like situation--a situation that requires the operator to be responsible for the time-sharing of functions at various levels of work load. The work is divided over the 2-hour performance period so that the operator is responsible for all three watchkeeping tasks continuously, but only part of the time for the three active tasks: (a) arithmetic computations during 30 minutes of each 2-hour period, 15 minutes in combination with the watchkeeping tasks only, and 15 minutes with the group-performance procedural task of code-lock solving as well; (b) code-lock solving during half of each 2-hour period, 15 minutes with arithmetic computations and watchkeeping, 30 minutes with watchkeeping alone, and 15 minutes with watchkeeping and target identification, and (c) target identification during 30 minutes, half as indicated (with watchkeeping and code-lock solving) and half with the watchkeeping tasks only. Thus, relative demands on performance are low, intermediate, and high,

depending on whether the watchkeeping tasks are presented alone, with only one of the active tasks, or with two of them.

#### Preparation of MTPB Equipment for BRASP Series

The equipment used for the programming, task presentation, and data collection of MTPB studies consists of electromechanical devices specifically constructed for long-term MTPB studies. This equipment, constructed in 1967 under support of U.S. Army Medical Research and Development Command, Department of the Army Research Contract No. DA-49-193-MD-2567, is, under normal conditions of maintenance, very reliable. In the past 10 years, however, the equipment has been utilized in more than 10 long-term studies, and careful preparatory maintenance is required to insure its continued reliability. Consequently, a major effort during the period of December 1977 through February 1978 centered around the preparation of the MTPB equipment for use in the proposed series of studies. Maintenance of this equipment has continued through the grant period on an as-needed basis.

A memorandum series was initiated during the reporting period to provide a permanent record of the detailed planning and implementation associated with the BRASP series of studies. This series serves to document the details involved in the conduct of this effort.

The BRASP Series--During the month of December 1977, detailed plans for the series of MTPB studies were formulated to achieve the above objectives. This series of studies, referred to as the BRASP series (for Biological Rhythms And Sustained Performance), consisted of 7 studies, each of which was conducted in three phases (excepting BRASP-7 which involved only the first two phases).

Phase 1 or the Training Phase of each study consisted of 48 hours (24 2-hour periods) of performance on the MTPB in which the subjects worked on the battery for four hours per day for twelve days. The twelve days were generally distri-

buted over four weeks during which the subjects worked for three days each week, although distribution of the twelve days in some cases were confined to a two-week period with six days per week. Past research with the MTPB has established that 48 hours of training with the tasks of the battery are necessary in order for the subjects to reach asymptotic levels of performance in the time-sharing requirements of the battery. Data for a total of 40 subjects were obtained for this phase of the study.

Phase 2, the Sleep-loss Phase, of each of the studies followed the format previously employed in similar studies with male subjects. Specifically, seven consecutive days were required for this phase with the first two days providing 16 hours of baseline performance, the last two days providing 16 hours of recovery data, and the middle three days providing 48 hours of continuous-work and sleep-loss data followed by 24 hours of rest and recovery. Consequently, on Monday and Tuesday of each sleep-loss week, subjects were required to work for 8 hours each day following a 4-4-4-12 work-rest schedule (i.e., 4 hours on duty, 4 hours off, 4 on, and 12 off). The beginning of the continuous-work period began on Wednesday, and the subjects were required to work at the MTPB for 48 continuous hours for a total of 24 cycles through the basic 2-hour performance period. Immediately following the period of continuous work, subjects received 24 hours of rest and recovery, the first 12 of which was spent under supervised sleeping conditions in the Performance Assessment Laboratory. Subsequent to the rest-and-recovery period, the subjects were required to work the MTPB for two additional days following the 4-4-4-12 work-rest schedule.

During Phase 3 of each study, the Cycling Phase, the subjects, except those in BRASP-7, performed the tasks of the MTPB for five additional weeks with 12 hours per week of performance in blocks of 4 hours. The distribution of the three test periods within each week was spread as much as possible through the week so as to provide adequate sampling of any changes that may have occurred during the testing period.

In summary, each of the five subjects in each of the studies performed the tasks of the MTPB for a total of 188 hours--48 hours of training, 80 hours during sleep-loss week, and, except for BRASP-7, 60 hours during the cycling phase. These performances provided a total of 1410 performance measures per subject per study; in addition to these individual performance measures, a total of 1320 measures of crew performance on the code-lock solving task were obtained for each study.

A variable of primary interest in these studies was a comparison of the performances of normal cycling females with the performances of females using contraceptive pills. Consequently, it was decided that half of the subjects in the studies would be normal cycling females and the other half would be females using contraceptive pills. It was further decided that, factorial to the normal vs. pill factor, the phase of the menstrual cycle at the time of sleep loss was a factor of major interest. Consequently, half of the subjects were to enter sleep loss within 24 hours of the onset of menstruation, and the other half were to enter sleep loss during mid-cycle. Earlier discussions of the proposed design considered the inclusion of a third factor to be included in the sleep-loss investigation--the starting point of sleep loss relative to the diurnal cycle; this factor has been found to be an important factor in experiments involving male subjects. However, to maximize power for the above two factors, it was decided that the diurnal cycle factor would not be investigated in this series of studies and that a single level of that factor would be employed. Thus, the sleep-loss period for each of the studies began at 8:00 A.M.

To summarize the general design of the sleep-loss phase of the studies, there were four conditions resulting from the factorial combination of cycling type (i.e., pill vs. normal) and cycle phase at time of sleep loss (i.e., menstrual vs. mid-cycle).

In the end, seven of the 35 subjects studied during the sleep-loss phase were at an inappropriate point in their menstrual cycles at the start of the sleep-loss period, and, therefore, their data could not be used. Data were obtained for seven subjects who were normally cycling, mid-cycle; for five who were normally cycling, menstrual; eight who were pill, mid-cycle; and eight who were pill, menstrual.

In order to avoid possible demand-characteristic effects, as well as for practical reasons related to scheduling of subjects, it was further decided that the crews comprising the seven studies would consist of a mixture of the four conditions in so far as possible.

The five weeks of the cycling phase of each of the studies was viewed as the assessment of MTPB performances as a function of the menstrual cycle. Having operated the MTPB tasks for a total of 128 hours prior to the cycling phase, each subject had achieved a very stable asymptotic level of performance. Thus, data from this phase could be rearranged so that all subjects are aligned according to the menstrual cycle and, thus, provide accurate assessment of any possible interaction of the MTPB performance with the menstrual cycle. The limitations of time and available funds precluded testing the BRASP-7 subjects in this phase of the study, but data on 30 subjects, 15 using contraceptive pills and 15 normally cycling, were obtained.

PAL ITR-79-22 has been completed and fully describes the results of the BRASP series of studies.

## 2. Supporting Laboratory Research

Although the BRASP-series is considered the major thrust of this research project, the design and implementation of a number of smaller-scale supporting laboratory investigations was considered to be important contributions made by the project. Accordingly, several such investigations were designed and conducted during the grant period.

The Menstrual Cycle and the Capacity for Physical Work--An investigation was designed and conducted during the grant period that attempted to determine the effects of the phases of the menstrual cycle on capacity for physical work. Specifically, thirteen normally cycling females were selected to serve as subjects in a study that required them to pedal to exhaustion on a bicycle ergometer every other day for two complete menstrual cycles. Work capacity was measured by the time to exhaustion on the ergometer when the subject maintained a specified level of cycling while the exercise workload was increased by 100 kpm per minute. In addition, the subject's heart rate was recorded continuously for per-minute summaries, as well as subjects' reports of subjective ratings of perceived exertion at the end of each minute of performance. It was anticipated that the subjects will reach asymptotic levels of performance by the end of the first menstrual cycle so that the second cycle should be free of any training effects. The physical, physiological, and subjective measures were subsequently analyzed to determine what, if any, are the effects of the menstrual cycle. Each of the subjects was required to obtain a physical examination with electrocardiogram and to be certified capable of strenuous exercise by a physician. ITR-79-20 presents the details and results of this study.

Sleep Loss and Information Processing Rate in Males and Females--This study was designed to determine the effects of 36 hours of sleep loss on specific measures of information-processing rates in both males and females. Specifically, during 36 hours of sleep loss, the choice-reaction time (CRT) performances of six males and six females were measured under two different conditions of stimulus-response compatibility and five levels of number of alternatives; through the time course of the sleep-loss period, the subjects' performances were ascertained at seven specific test points with an additional testing following 20 hours of rest and recovery. These performances were compared to a control group (of identi-

cal composition) who performed the task under similar test sessions without sleep loss. PAL ITR-79-21 presents the details and results of this study.

Sleep Loss and Critical Flicker Frequency in Males and Females--This study was designed to measure the changes in the critical flicker frequency in both male and female subjects at several points during a 36-hour sleep-loss period, as well as in control subjects measured an equal number of times, but without sleep loss. Critical flicker frequency has been reported to vary with the effects of various stressors on subjects, and this study is directed toward determining if that finding holds for the stress associated with sleep loss, and possibly assessing the extent to which various amounts of sleep loss are stressful as compared to other stressors. Also, differential effects of sleep loss on the critical flicker frequencies of male versus female subjects have important implications. The results of the study suggested the need for replication with a longer sleep-loss period. Therefore, a second study in which 10 female subjects were studied than 48 hours of sleep loss was conducted. It is planned that the results of both studies will be published in the open literature.

Sleep Loss and Psychomotor Performance in Males and Females--This study was designed to assess the effects of 36 hours of sleep loss on psychomotor performance of male and female subjects as compared to controls who were measured an equal number of times, but who did not experience the sleep-loss period. These data in combination with those of the effects of sleep loss on information processing provide measures of eight of the eleven factors of psychomotor performance identified by Fleishman (Fleishman, E.A. Human abilities and the acquisition of skill. In E.A. Bilodeau (ed.), Acquisition of Skill, New York: Academic Press, 1966). Therefore the possibility that sleep loss has differential effects on different aspects of psychomotor performance can be assessed; also, interaction

of these effects with the sex of the subjects will be revealed. Data collection and analysis for this study has been completed. It is planned that the results will be published in the open literature.

Sleep Loss and Memory in Males and Females--This study examined the effects of sleep loss on different types of memory for verbal materials in male and female subjects. More specifically, memory for specific factual material was compared to memory of a more general nature that permits valid inferences to be made based on the material remembered. Memory effects due to learning prior to sleep loss with testing during the sleep-loss session as well as due to learning during the sleep loss session with testing after recovery from the sleep loss were studied. Also, control subjects receiving the same treatments except for experiencing sleep loss were included. The results of this study were sufficiently ambiguous that no further effort devoted to them is considered worthwhile.

Annotated Bibliography of Physiological Changes Associated with the Menstrual Cycle--An extensive review of the literature regarding the physiological changes associated with the menstrual cycle and their effects on behavior was conducted under the direction of Dr. P.J. Mikulka (Professor of Psychology). Based on this review, PAL ITR-78-17 has been prepared that presents a summary of the findings.

Annotated Bibliography of Psychological Changes Associated with the Menstrual Cycle--A review of the literature regarding psychological changes associated with the menstrual cycle was conducted under the direction of Dr. H.B. Gillen (Assistant Professor of Psychology). A bibliography of the studies in this area has been prepared for internal use only and no ITR's presently anticipated.

Sleep loss and field dependency in females--This study examined the effects of 48 hours of sleep loss on the field dependency of 10 female subjects. Field



dependency was measured with the rod and frame apparatus. Since prior research suggests that field dependency is one of the qualities that vary with the sex of the subject, possible variations in it with sleep loss in female subjects has potential important implications. Data collection for this study has been completed and the data are presently being analyzed. If the results are sufficiently meaningful, a report of the study will be published in the open literature.

#### LIAISON ACTIVITIES

The following presentations have been to date of the results obtained from research supported by this grant:

G.D. Coates and R.H. Kirby - Physiological influences upon the work performance of men and women. Paper presented at the Review of Air Force Sponsored Basic Research in Environment and Acceleration Research. Colorado Springs, September 1978.

G.D. Coates and R.H. Kirby - Effects of 48 hours continuous work and sleep loss on work performances of males and females. In B.B. Morgan, Jr. (Chair), Sex: The new independent variable in performance assessment research. Symposium presented at the meeting of the Southern Society of Philosophy and Psychology, Norfolk, April 1979.

N.K. Eberhardt, E.A. Alluisi, G.D. Coates and R.H. Kirby - Effects of sleep loss on the rate of gain of information in males and females. In B.B. Morgan, Jr. (Chair), Sex: the new independent variable in performance assessment research. Symposium presented at the meeting of the Southern Society of Philosophy and Psychology, Norfolk, April 1979.

S.J. Miller - Menstrual cycle and training effects on physical work capacity. In B.B. Morgan, Jr. (Chair), Sex: the new independent variable in performance assessment research. Symposium presented at the meeting of the Southern Society of Philosophy and Psychology, Norfolk, April 1979.

S.J. Miller, G.D. Coates and R.H. Kirby - Effects of 48 hours of continuous work and sleep loss on work performance of males and females. Paper presented at the annual meeting of the Human Factors Society, Boston, October, 1979.

#### STATEMENT REGARDING INVENTIONS AND DISCOVERIES

During the report period, there were no discoveries, inventions, or other patent actions associated with personnel or activities thereof under support of this grant.

## PROFESSIONAL PERSONNEL

The following individuals participated in the activities of this project during the reporting period: Glynn D. Coates, Ph.D.; Raymond H. Kirby, Ph.D.; Nancy K. Eberhardt, M.S.; Sarah J. Miller, M.S.; Earl A. Alluisi, Ph.D.; P.J. Mikulka, Ph.D.; H.B. Gillen, Ph.D.; W.L. LeHew, M.D.

## SUGGESTIONS FOR FUTURE WORK

Future work on the research reported herein and in the accompanying ITRs should address three major issues. Firstly, the effects found in the BRASP series, particularly those showing superiority of women in withstanding the effects of continuous work and sleep loss should be replicated on greater numbers of subjects, and perhaps extended to a more heterogeneous sample of subjects. Secondly, the interaction between the effects found and the circadian rhythms of the subjects should be addressed. Thirdly, the length of time required for women to recover from the effects of sleep loss should be investigated and compared to existing data on male subjects (Morgan, Coates, Brown and Alluisi, 1974; Alluisi, Coates and Morgan, 1977).

\* \* \* \* \*

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